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Efficiency of the Sonar Fish Protection Device at the Kokaral Dam of the Small Aral Sea

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Abstract

The study aimed to assess the efficiency of the pilot sonar (hydroacoustic) fish protection device (FPD) installed at the Kokaral Dam of the Small Aral Sea. For this purpose, between August 27 and September 5, 2020 experimental and control fish catching was carried out using fixed fishing nets (30x60 mm mesh). The FPD's effectiveness was assessed based on the amount and species diversity of the caught fish with and without the FPD operating. Fish behavior and distribution were monitored using an echo sounder. In terms of quantity, the total of 173 fish were caught with the FPD off, and 94 with the FPD on. In terms of biomass, the values were 37.5 kg and 27.6 kg, respectively. With the FPD off, the ichthyofauna composition was represented by 12 fish species: common carp, crucian carp, roach, ide, bream, rudd, saber carp, snakehead, pikeperch, perch, pike, and asp. With the FPD on, roach and ide were absent in the catch, and the quantity of rudd significantly decreased. In both catches, the quantity of common carp and crucian carp was similar; bream and saber carp specimens were sporadic. The number of predatory fish (pike, perch, snakeheads, and pikeperch) in the catches increased. Asp was absent in the net catches also; however, this fish species represents the main object of amateur hook and line fishing. Based on the catch-per-effort unit, it can be concluded that whereas the FPD demonstrated efficiency – for small non-predatory fish like ide, roach, and rudd it was 95%, it was 0% for large non-predatory fish (carp and crucian carp); and negative for predatory fish.

Keywords: Kokaral Dam, Small Aral Sea, fish protection device, hydroacoustic, ichthyofauna.

1. Introduction

Intensive water management in the Syrdarya and Amudarya River Basins over the past 40 years has threatened the very existence of the Aral Sea.

In the late 1980's, due to the shallowing of the Aral Sea, its northern part split from the southern one. A connecting channel had emerged between them – via it, the water flowed from the Small (Northern) Aral to the Large (Southern) Aral Sea. As a result of increasing water mineralization and installation of new aquatic invertebrate and fish species, its fauna had undergone significant changes (Aladin et al., 1998; Aladin, Plotnikov, 2008). In order to improve the environmental situation and fishery capacity, the local authorities built an earthen dam in the Berg Strait to prevent water outflow from the Small Aral Sea. However, in the course of several years, the installation was often damaged, and labor was required to repair it. In the spring of 1999 – when the water level in the Small Aral Sea rose above 43 m – the dam was broken by the severe storm and was destroyed completely (Micklin et al., 2016).

During 1999-2005, based on the initiative of foreign and domestic groups of researchers and science experts, within the framework of the "Regulation of the Syrdarya River flow and the water level in the northern part of the Aral Sea", the Government of the Republic of Kazakhstan (RK) had built the Kokaral Dam and several other hydro-technical installations. The total amount of the corresponding complex and repair works amounted to 85.79 mln USD, including 64.5 mln USD allocated by the World Bank, and the remaining part – from the national budget (Andreyev, 1999; Novikova, 2019; Sikhanova et al., 2014). The dam's length is 13,034 m; width – up to 100-150 m; and height (at the crest) – 6 m (45.5 m, Baltic system). The project allowed restoring the Small Aral Sea (currently, the water level there remains stable at 42 m), decreasing water mineralization, as well as partially restoring its flora and fauna (Koshkarov et al., 2017; Nurgizarinov et al., 2014). The measures undertaken made it possible to improve the overall environmental situation in the area and gave impetus to the development of the fishing industry. However, the previously installed fish protection device in the form of a small-mesh net has deteriorated. The prolonged absence of a special fish protection device at the Kokaral Dam has led to mass accumulation of mature fish and young stock close to the dam. This is because the commercial fish species of the Small Aral Sea mainly spawn in the Syrdarya River, and accordingly all fish as well as migrating offspring get caught in the zone of the strong current carrying them down to the dam's spillway. As a result, all fish passing through the gateway die due to the excessive salinity of the Southern Aral Sea.

Currently, over 20 fish species inhabit the sea, including commercial (Nurgizarinov et al., 2016). According to the Fishery Research and Production Center (FishRPC), the damage to fish stocks from water discharge without the FPD at the Kokaral Dam exceeds 53 mln specimens, or 4,000 tons (adult fish), and 30 mln specimens, or approx. 1,000 tons (young stock) annually. The Fishery Rules of the Law of the RK "On the Protection, Reproduction and Use of the Animal World" and Order №190 of the Ministry of Agriculture of the RK of July 24, 2015 (On the introduction of restrictions..., 2015) state that in order to prevent mass

fish dying in the Aral-Syrdarya Basin, fishing shall be allowed in the downstream of the Kokaral dam and the channel connecting the Small and Large Aral Seas.

To address the challenge of mass fish accumulation at the Kokaral Dam, Kazakhstan scientists proposed a project to install a hydroacoustic (sonar) fish protection device (Isbekov et al., 2013); the idea was approved, and the FPD was experimentally installed in May 2020. This FPD is based on the hydroacoustic method of repelling fish preventing its further adaptation to the sound. Not reaching the dam by 150-200 m, the fish is supposed to return to the Northern Aral Sea, thus reducing the damage to the local fishery stock.

According to SNiP 2.06.07-87 for fish protection installations, an FPD's efficiency should be at least 70% for commercial fish larger than 12 mm (SNiP, 1989). However, special equipment does not always protect fish juveniles and other aquatic inhabitants, since the installation and proper operation of FPDs are rather expensive. This makes the theoretical elaboration of new types of FPDs and their experimental deployment at large domestic water intake facilities relevant.

This research aimed to examine the performance of the hydroacoustic FPD undergoing pilot testing at the Kokaral Dam.

2. Research area

The research site is located in the southwestern part of the Small Aral Sea close to the Kokaral Dam (Fig. 1). The dam has a culvert with 9 spillways discharging water into the Southern Aral Sea. In the dam pre-mouth area, 15 pontoon (floating) units with anchor mounts were installed to support the sonar FPDs.

In the water supply channel at the site of FPD installation, the depths are tied to water level fluctuations averaging 1.5 m at the shore and 4.2-4.4 m in the mid-section. The mean water flow speed in the channel – 80 m away from the spillway – is 0.15-0.20 m/s. However, the flow rate in the channel may weaken or, conversely, increase with lower or higher water flow going through the dam spillway. The width of the water supply channel at the site of FPD installation is 125 m (see the schematic map of the research area in Fig. 1).

The hydrological regime of the Small Aral Sea is predetermined by the water regime of its main feeding source – the Syrdarya – regulated by upstream water systems and corresponding water releases; in their turn, their runoff is affected by off-season fluctuations. As a result of large winter releases along the river, by mid-April the water level reaches its highest – 42.5 m, Baltic system. Starting April, the influx of water into the sea partially reduces due to water withdrawal for agricultural (irrigation) purposes

According to Kazhydromet, in 2018 the highest water level of the Small Aral Sea reached 42.22 m, Baltic system during April-May, with the sea's water area reaching 3,332 km^2. Recently, seasonal sea-level fluctuations – summer maximum and winter minimum – are virtually regular.

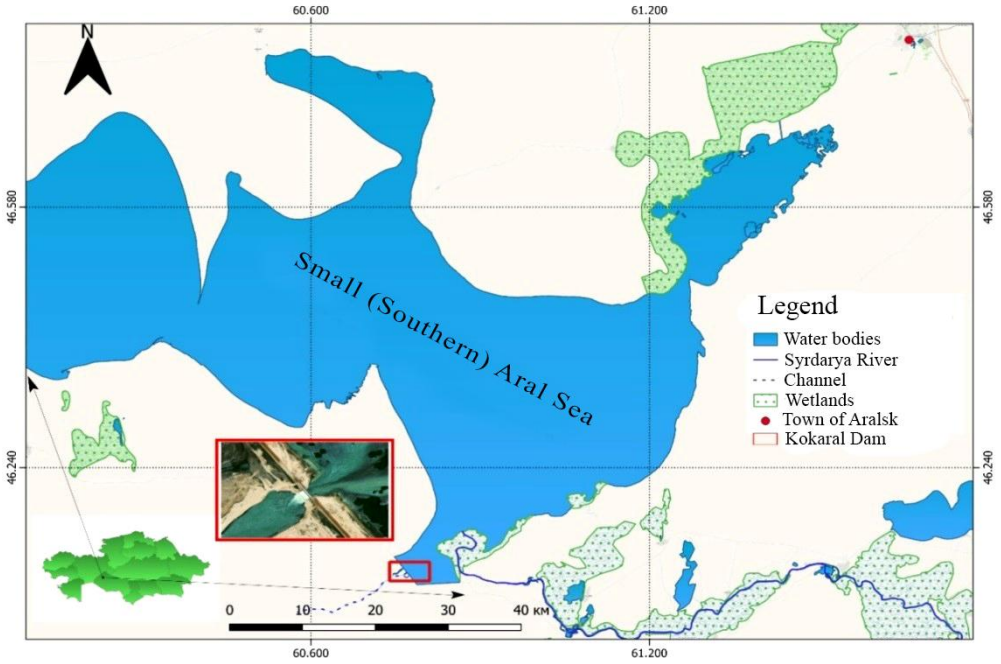

Figure 1. Geographic location of the Kokaral Dam.

The general view of the head and ebb sides of the dam is shown in Fig 2, clearly depicting the water flow volume and nature of movement directed into the dam culvert by the side slopes.

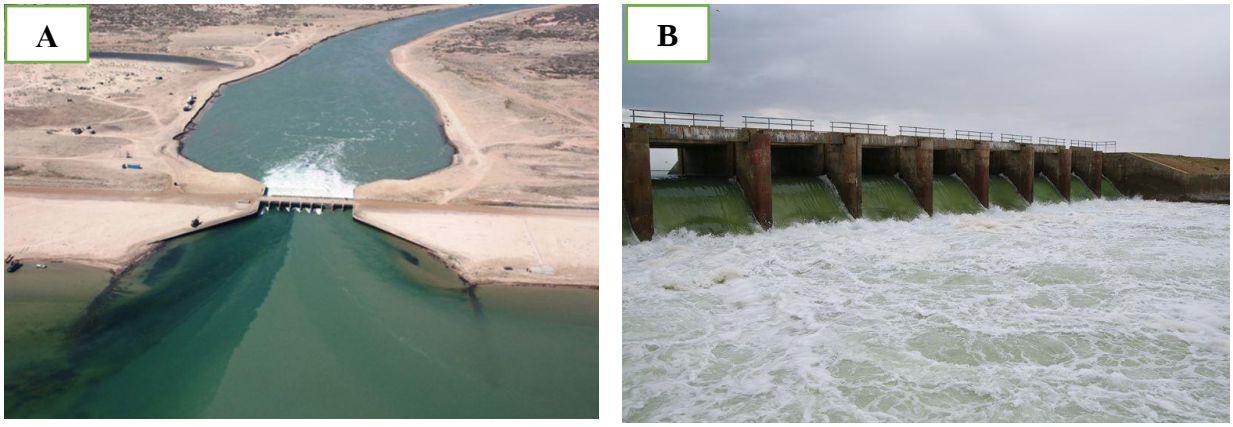

Figure 2. General view of the Kokaral Dam from (A) head and (B) tail water sides (Source: Mapio.net, Aral District, n.d.)

1.1. Background

Worldwide, different reservoir and wetland ecosystems face multiple anthropogenic stressors (Tesch & Thevs, 2020). As a result, their abundant biological resources have been reducing dramatically (Dudgeon et al., 2006). It is known that because of intensive fishing, numerous fish populations have sharply dropped, and small-size fish are replacing large and valuable commercial species (Roberts & Hawkins, 1999). As the dynamics shows, the

dimensional-weight profile of commercial fish species has been going down every year, and the cenoses demonstrate more and more fish juveniles, which have not reached reproductive phase. The current rate of decline in the quantity of valuable commercial fish is extremely high, and more attention should be paid to preserving their populations (McCusker et al., 2017).

Some researchers suggest that in 20 years – due to the construction of HPP dams – the number of large rivers on the planet will decrease by 20% (Zarfl et al., 2015). Construction of special use hydro-technical installations, pollution, commercial fishing and hunting, and biological invasions expose river ecosystems to adverse anthropogenic impacts (Magurran, 2009). Loss of species diversity and change and/or disappearance of biotopes in continental reservoirs has been taking place much faster than in terrestrial or oceanic systems (Harrison et al., 2018; Strayer & Dudgeon, 2010). Central Asia continues to lag behind developed countries as to studying, assessing and preserving its biodiversity (Darwall & Freyhof, 2015; Meyer et al., 2015; Pelayo-Villamil et al., 2018).

FAO's Report on Fisheries and Aquaculture No.1045 (April 2013) devoted to the development of fisheries and aquaculture in Central Asia and the Caucasus, recognized the constructions of fish-ways and fish protection devices as a priority. FAO's recommendations on responsible fishery management emphasize the mandatory nature of compensating for adverse impacts on fishery water bodies by way of installing effective fish protection devices, organizing fish-ways, etc. at new water intake (spillway) facilities, as well as monitoring the efficiency of already operating FPDs (Code of Conduct for Responsible Fisheries, 2011).

For the first time, the issue of protecting fish from entering water intakes was raised in the US, where in the 1920's they started installing mesh, and later louver, fish protection devices at irrigation water intakes. Yet, the problem was not solved completely, although in western countries only salmon fish species are under special protection.

The fish protection methodology assumes following certain principles. They were first formulated by Nusenbaum (1967), and then Pavlov and Pakhorukov in their monograph "Biological Basis of Fish Protection against Entering Water Intakes" (1973). Further (starting early 1980's) the research on ways to protect young fish based on its re-concentration inside the water stream with natural or artificial installations made it possible to develop SNiP 2.06.07-87 "Fish-way and fish protection installations" (1989) still in effect in Kazakhstan.

Complicated hydrological (large-scale water passage – from 395 to 753 m^3/s) and meteorological (destroying impacts of ice cover during winter and moving ice plates during spring) condition in the Kokaral Dam head section make standard – mechanical, mechanical-hydraulic and physiological (air bubble curtain, electric field) – FPDs inefficient. Moreover, chemical and optical means of fish protection, as well as the deep-water intake method are likewise unsuitable for the Kokaral Dam.

To avoid the ice cover and ice movement impacts compromising the water flow, as well as to address the issue of mass fish accumulation close to the Kokaral Dam, based on Patent №27636 "Deep Hydroacoustic Complex for Deterring Adult and Young Fish from Hydro-Technical Installations" (Isbekov et al., 2013) Kazakhstani scientists proposed the

corresponding project, that was approved, and in May 2020 the pilot unit was installed under the joint Project "Ensuring safety, conservation and development of fish stocks in the Northern Aral Sea region".

1.2. Operating principle of the FPD at the Kokaral Dam

The FPD is located 80 m away from the dam spillway; the channel width at the site of installation is 125 m. The slightly convex FPD line consists of 12 hydroacoustic modules with individual floating supports. The line of hydroacoustic modules represents a closed shore-to-shore circuit passing across the entire width of the water supply channel. The floating supports have separate fixing anchors, and are connected by steel ropes; at its edges, the FPD circuit is fixed to the shores with moorings (Fig. 3).

The principle of the FPD operation is based on the deterring exposure of fish to a sound field of intensely and continuously transforming force and tonality with enhanced sound wave energy density, preventing fish from adapting to the sound.

Figure 3. Floating units supporting underwater speakers close to the Kokaral Dam (August, 30, 2020).

Via cable, the onshore control unit fitted with a broadband stereo player (Fig. 4A) transmits the digital sound stream of at least 120 phons and energy density of at least 2 W/cm^3 to underwater speakers emitting the sound into the water in the upward direction (Fig. 4B). This fish protection device uses US-manufactured underwater sonar equipment.

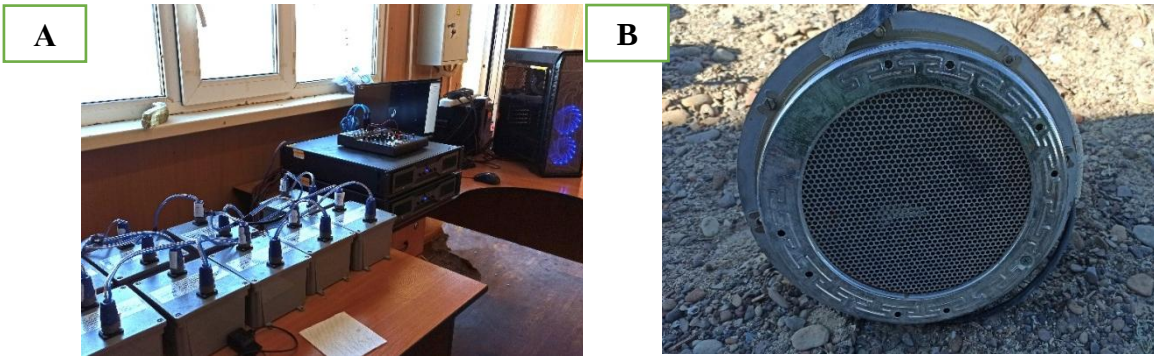

Figure 4. General view: (A) Control unit and (B) FPD underwater speaker installed close to the Kokaral Dam (August 30, 2020).

The broad capabilities of modern digital audio recording allow creating various acoustic signal versions not allowing fish to adapt to the sound field. Intense sound waves with enhanced energy density likewise affect fish soft tissue and air bladder. The effective repelling sound field is 6 m wide.

2. Research methods

Data collection, processing and presentation were carried out as per the Rules of Executing Biological Justification on the Use of Fauna approved by Order №104-Ө of the Minister of the Environment and Water Resources of the RK of April 4, 2014 (On Approval of Rules of Executing..., 2014).

The experimental and control fish catches with set nets (30, 40, 50 and 60 mm mesh) were carried out from August 27 to September 5, 2020 in the head water of the Kokaral Dam (46°6.151'C, 60°46.183'B), where the sonar FPD is installed – 2 days in a row with the FPD off, and then 2 days in a row with the FPD on (Fig. 5A). The nets were installed near the gateway and upstream of the floating pontoon circuit. Additionally, a survey was conducted among amateur fishermen using hook gear with simultaneous analysis of their catch.

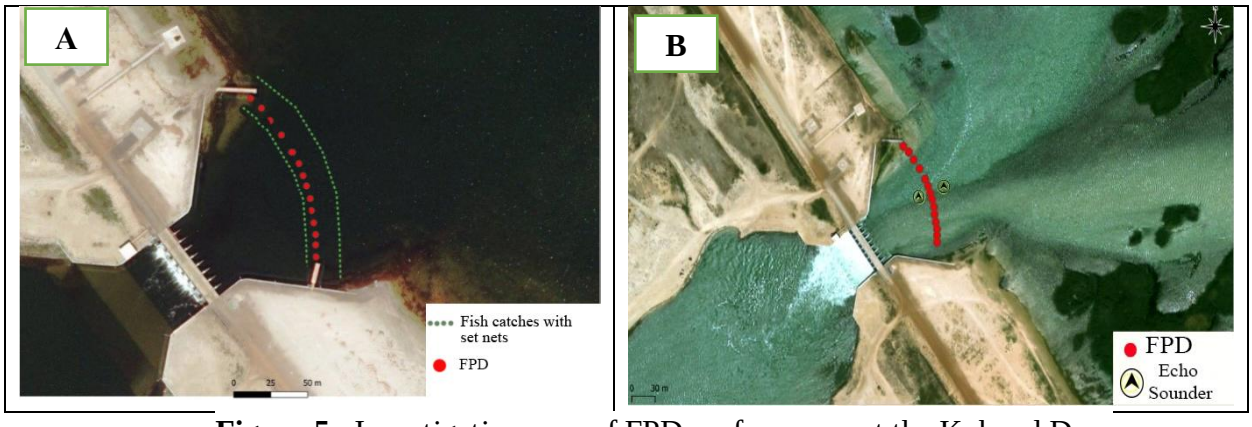

Figure 5. Investigation area of FPD performance at the Kokaral Dam (A – net set up; B – echo-sounder installation points).

The comparison was done based on the net catching efficiency with the FPD in the off and on modes. Fish behavior and distribution in the FPD area were observed using the Humminbird Helix 7 Echo Sounder (Fig. 5B). The Fish ID parameter was additionally plugged in to allow the echo sounder to separately register fish movement under water. Depth measurements were done via the echo sounder; and width and length measurements – using the satellite GPS.

The general biological analysis of fish was carried out in the field as per the generally accepted methods (Pravdin, 1966), including number, biomass, sex and species composition with the account of size-weight and age profile (Kalaida, Govorkova, 2013). Fish age and linear growth were determined by scales (Mina, 1976).

The assessment of the FPD performance was executed as per Order №221 of the Minister of Agriculture of the RK *On Approval of Requirements for Fish Protection Devices at Water Intake Facilities* of May 31, 2019 (On Approval of Requirements..., 2019) based on the number and species of fish caught in the net with the FPD turned off and on.

MS Excel was used for data statistical processing and other calculations.

3. Results

By the methods of passive (set net) and active (fishing rod) catch, in the research area 267 fish specimens belonging to 12 species were registered (Table I).

Table I. List of fish species detected in the dam's headwater section (Aug 27-Sept 05, 2020).

№	Common name	Latin name	Catch (net, mm; or rod)	Total number
1	Common carp	*Cyprinus carpio*	30, 40, 50, 60	7
2	Bream	*Abramis brama*	60	1
3	Crucian carp	*Carassius gibelio*	30, 40, 50, 60	20
4	Ide	*Leuciscus idus*	40, 50	11
5	Roach	*Rutilus rutilus*	30, 40, 50	25
6	Rudd	*Scardinius*	30, 40, 60	71
7	Sabre carp	*Pelecus cultratus*	30	2
8	Asp	*Leuciscus aspius*	fish-rod	-
9	Perch	*Perca fluviatilis*	30, 60	64
10	Pikeperch	*Sander lucioperca*	30, 40	9
11	Snakehead	*Channa argus*	30, 40, 60	6
12	Northern pike	*Esox lucius*	30, 40, 50, 60	51
TOTAL:				**267**

Mass accumulation of fish, especially commercial species, is observed in the headwater section of the Kokaral Dam. Based on the survey, in spring and summer some local fishermen reported catching an average of 20-40 tons of fish per one seine drag. The corresponding data recorded by local fish inspectors and/or reports of research organizations are lacking, since the dam's upstream section is subject to the year-round fishing ban.

Judging by the quantity of fish swimming on the ebb side of the dam, it can be argued that huge amount of fish pass through the culverts. The absence of a fish-way exacerbates the situation, since the fish that had passed the gateway cannot go back.

In summer, the water level in the Syrdarya River falls significantly because of irrigation withdrawal along its upper reaches. Due to that only 1 of 9 culverts was opened to keep the water at the designated level and supply oxygen to the fish inhabiting the tail bay.

Within the research area, fish accumulation was observed both in the head and ebb sections of the dam. The echo sounder recorded the movement of all ichthyomass regardless of fish size or weight. Several asp specimens were caught only using the fishing rod. All the fish encountered in the research area were of commercial value.

On August 28, 2020, with the FPD off 9 fish species were caught using the net: total number – 77 specimens weighing 17.01 kg. In terms of quantity, perch, roach and northern pike dominated, amounting to 37.6%, 20.78% and 11.69% of the catch, respectively. The age profile of the caught fish was represented by specimens aged 3+ to 6+ years. Almost 80% of the fish were caught using the 30 mm mesh net (Table II).

Table II. Catch-per-effort in the Kokaral Dam headwater without FPD (Aug 28, 2020).

Fish species	**Net-mesh, mm**				**Total number**
	30	**40**	**50**	**60**	
Common carp	-	-	-	2	2
Crucian carp	-	-	-	4	4
Roach	14	2	-	-	16
Ide	-	2	4	-	6
Rudd	8	-	-	-	8
Pike	9	-	-	-	9
Perch	29	-	-	-	29
Snakehead	-	-	-	1	1
Pikeperch	-	2	-	-	2
TOTAL:	**60**	**6**	**4**	**7**	**77**

On August 29, 2020, the control net set up (with FPD off) at the same site allowed catching 8 fish species: total number – 96 specimens weighing 20.49 kg. In terms of species and biomass, rudd dominated – 61.5% and 38.9% of the catch, respectively. Roach and northern pike formed the subdominant group. In addition to other species, the catches by local amateur fishermen included asp. All specimens subjected to biological analysis were sexually

mature, and the condition of their germ glands corresponded to maturity phase III. The age profile of the caught fish ranged between 2+ and 8+ years. The analysis of the net catch revealed that in terms of quantity the main catch was done using nets with 30 mm mesh, and in terms of biomass – 60 mm mesh (Table III).

Table III. Catch-per-effort in the Kokaral Dam headwater without FPD (Aug 29, 2020).

Fish species	**Net-mesh, mm**				**Total number**
	30	**40**	**50**	**60**	
Common carp	-	1	-	1	2
Crucian carp	-	2	-	4	6
Roach	-	-	9	-	9
Ide	-	5	-	-	5
Rudd	56	2	-	1	59
Pike	-	-	-	9	9
Perch	-	-	-	5	5
Pikeperch	-	1	-	-	1
TOTAL:	**56**	**11**	**9**	**20**	**96**

The site was also surveyed using the echo sounder with the sonar FPD off. The survey results showed fish movement in the area mainly at the depth of 1.2-4 m (Fig. 6). In addition, with the 10-minute observation interval, fish movement was taking place continually.

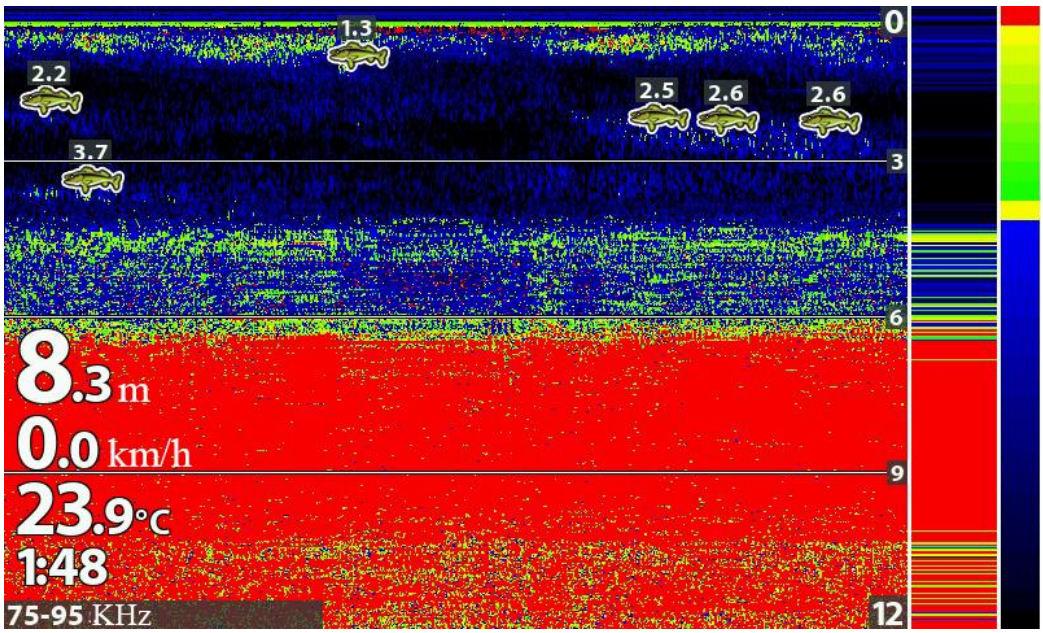

Figure 6. Real-time echo-sounder monitoring of fish movement in the Kokaral Dam's headwater (with FPD off).

On September 2, 2020, significant changes were observed in the fish catching frequency (with different fishing gear) in the zone of the FPD's effective coverage near the Kokaral Dam. The net catch showed a significant reduction in the fish quantity and biomass, i.e. only 50 specimens were caught in total weighing 13.74 kg. Roach and ide were absent in the catch altogether. Only individual sabre carp specimens were encountered. The number of caught crucian carp, common carp, snakeheads and pikeperch ranged from 2 to 4 specimens. Northern pike and perch dominated in terms of number and biomass – their share generally exceeded 70% of the total catch (Table IV).

Table IV. Catch-per-effort in the Kokaral Dam headwater with FPD on (Sept 02, 2020).

Fish species	**Net-mesh, mm**				**Total number**
	30	**40**	**50**	**60**	
Common carp	1	-	1	-	2
Crucian carp	1	-	1	1	3
Rudd	4	-	-	-	4
Pike	12	4	3	1	20
Perch	16	-	-	-	16
Snakehead	2	-	-	-	2
Pikeperch	-	2	-	-	2
Sabre carp	1	-	-	-	1
TOTAL:	**37**	**6**	**5**	**2**	**50**

During the control catches on September 3, 2020, the nets were installed up- and downstream of the continually operating FPD. The results of the catch demonstrated the decreased quantity and species diversity among the fish caught. Closer to the FPD – where small-cell (30- and 40-mm mesh) nets were installed, the catch mainly included common carp, pike, perch, snakehead and pikeperch. The net (50 mm mesh) installed prior to the fish protection device caught only 7 crucian carps and 1 bream. The control catches contained no roach, ide or rudd. The dominant group included northern pike and perch (61.4% of the total); crucian carp and pikeperch were included in the subdominant group (27.3%).

Table V. Catch-per-effort in the Kokaral Dam headwater with FPD on (Sept 03, 2020).

Fish species	**Net-mesh, mm**			**Total number**
	30	**40**	**50**	
Common carp	-	1	-	1
Crucian carp	-	-	7	7
Bream	-	-	1	1
Pike	13	-	-	13
Perch	14	-	-	14

Table V (continued).

Fish species	Net-mesh, mm			Total number
	30	**40**	**50**	
Snakehead	-	3	-	3
Pikeperch	5	-	-	5
TOTAL:	**32**	**4**	**8**	**44**

According to the echo survey results, with the FPD on fish distribution in the research area was registered at the depth of 3-4 m (Fig. 7). Yet, the spatial distribution of fish in the morning and evening was uneven, i.e. fish rarely appeared on the echo sounder monitor with the FPD on.

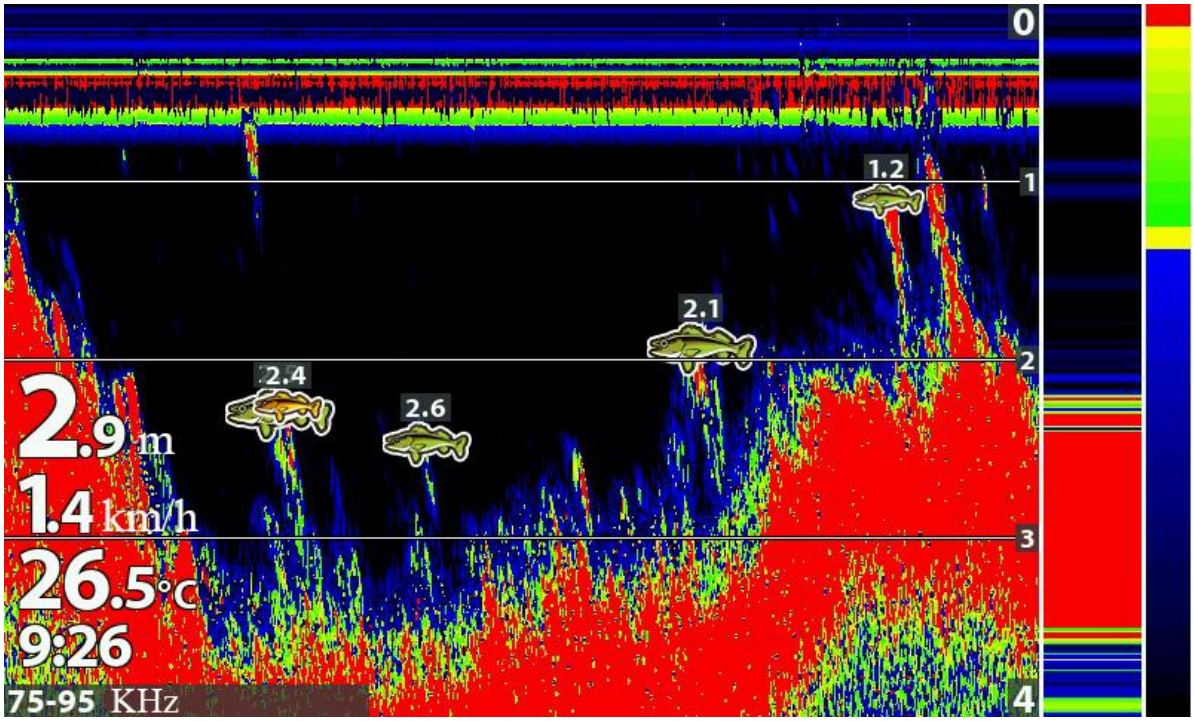

Figure 7. Real-time echo-sounder monitoring of fish movement in the Kokaral Dam's headwater (with FPD on).

The results of the ichthyological studies carried out using the hydroacoustic FPD near the Kokaral Dam are presented below (Fig. 8).

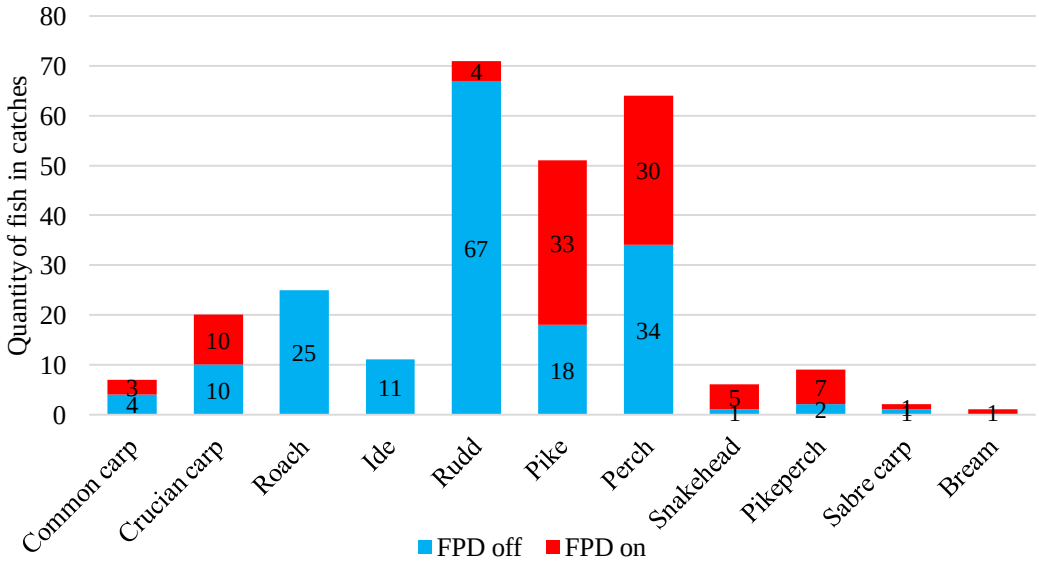

Figure 8. Quantity of fish caught using net with SFPD off and on close to the Kokaral Dam (2-day total).

With the FPD off, the ichthyofauna profile included 12 fish species, namely: common carp, crucian carp, roach, ide, bream, rudd, sabre carp, snakehead, pike, perch, pikeperch, and asp. No asp was encountered in the net catches, although it is considered the main target of amateur hook and line fishing.

With the FPD on, such species as roach and ide were absent in the net catches. The number of rudd significantly reduced, and only single specimens were caught. As to common carp, crucian carp, bream and sabre carp, no changes in their respective quantities in the catches were observed. The quantity of predatory fish in the catches (pike, perch, snakehead and pikeperch) grew.

Assessing the FPD performance in terms of species composition, it's effect is selective – i.e. deterring small non-predatory fish, having no effect on large non-predatory fish, and attracting predatory species. The quantity correlation turned out the following: with the FPD off – 173 specimens, and with the FPD on – 94 specimens, with the biomass correlation amounting to 37.5 kg and 27.6 kg, respectively.

Based on the catch-per-effort analysis, it can be concluded that the FPD efficiency for small non-predatory (ide, roach and rudd) was 95%; for large non-predatory fish (common carp and crucian carp) no effect was detected; and for predatory fish, the effect was negative.

4. Discussion

5.1. Performance of the hydroacoustic fish protection device

The performance analysis of the sonar FPD at the Kokaral Dam revealed that all age groups of ide, roach and rudd demonstrated an active desire to leave the device exposure area, hide in vegetation and/or go away from the dam. Thus, the sound transmitted by the device

had a deterring effect on them. With the FPD on, the net catches included no ide and roach, i.e. for these species the device's performance reached 100%, and 95% for rudd. Data analysis confirmed the FPD's high efficiency in deterring the fish species mentioned above from the dam.

As to common carp and crucian carp, their quantity in the catches did not alter with the FPD in the off or on modes. It can be assumed that the sound waves were not strong enough to affect the soft tissue and air bladder of these species, because they have a relatively large and elevated body. There is no explanation for sporadic specimens of bream and sabre carp, since these species are extremely rare at the time of the year when the research field mission was conducted.

Research data analysis likewise revealed that predatory fish, such as perch, pike, pikeperch and snakehead demonstrated passive tendency to leave the FPD's coverage area. Moreover, the sound emitted by the device might have had an attracting effect on these species – with the FPD on, the number of these fish in the catch increased 1.5-2 fold.

The absence of asp in the net catches may be due to its biological features, since it is a solitary open space predator.

Analyzing the limiting factors of investigating FPD efficiency, it is worth noting that at present there are no universal protective equipment guaranteeing 100% protection for fish of all species and at all stages of development (Beglyarov et al., 2019). In addition, it should be borne in mind that the field observations under this study lasted only 2 days. Such a short time does not allow fully tracking seasonal dynamics and/or variability due to weather changes. However, such a time period is sufficient to produce reliable primary data. The absence of a hydrophone to measure the sound background generated underwater represented another significant limitation of the study, as to have the deterring effect the sound should be at least 120 phons. It is likely that exactly this explains the insufficient FPD effect on large specimens and predatory species.

5.2. Species composition

According to the Aral Branch of the Fishery Research and Production Center LLP, currently the commercial fish ichthyofauna of the Small Aral Sea includes 18 species belonging to 5 orders: Cypriniformes (bream, white-eye, common carp, crucian carp, silver carp, grass carp, roach, rudd, ide, Caspian shemaya, and asp; Perciformes (European perch, pikeperch, and snakehead); Ecosiformes (northern pike); Siluriformes (Wels catfish); and Pleuronectiformes (European flounder). Of these species, 15 belong to aboriginal, and the remaining 3 species – european flounder, silver carp, and snakehead – are considered alien to this specific reservoir. The cyprinoids represent the richest species diversity (Yermakhanov et al., 2012). During several previous studies, such species as perch, ide, shemaya and crucian carp were designated as scanty, although in the catches under this research the quantity of perch was high.

In the Small Aral Sea, the share of bream is about 35% of the total fish stock and occupies the first place in catches. Nevertheless, according to our research (close to the Kokaral Dam)

it was encountered on occasion. Roach is the quantity dominant species in the estuary section of the Small Aral Sea, although it is widespread throughout the entire aquatorium (Yermakhanova, 2018). Its share in the sea fish stock amounts to 30%. The next dominant species in the sea is pikeperch – its percentage in catches exceeds 15%. Due to the intense desalination of the Small Aral Sea, pikeperch habitat has significantly expanded, and it is increasingly encountered throughout the entire marine environment (Plotnikov et al., 2016). The share of the remaining species in commercial catches is insignificant and fluctuates within 0.2-4%.

According to the findings of this study, without the FPD at the Kokaral Dam, the species diversity is represented by 12 species belonging to 4 families: Cyprinidae (common carp, crucian carp, roach, ide, bream, rudd sabre carp, and asp); Percidae (perch, pikeperch), Channidae (snakehead), and Esocidae (northern pike). The analysis of the commercial fish species profile at the Kokaral Dam pointed to a certain quantitative difference, i.e. the main dominant species there were rudd and perch, while roach and northern pike were part of the subdominant group. Thus, it appears that the bulk of these fish species concentrate at the river mouth and roll downstream. Mature and juvenile roach and rudd represented the majority in the ebb dam section.

Singular bream specimens encountered during the study can be explained by the fact that it mainly inhabits the river delta and its floodplain system. In addition, at the time of the field study sabre carp prefers to feed in desalinated sea sections. The number of other species corresponded to previous studies. Considering the quantity of predatory fish detected close to the dam, it is noteworthy to highlight their biological features, since a lot of fish comprising their main diet concentrate in this water zone.

6. Conclusion

The main achievement of this study was obtaining consistent preliminary data on the sonar FPD performance for each fish species – 3 fish groups were identified responding to the FPD differently.

Based on the results of the net catch, it is possible to draw the following preliminary conclusions:

- The sound waves emitted by the sonar fish protection device have demonstrated high efficiency for small non-predatory fish (ide, roach and rudd), serving a good indicator of deterring these fish species away from the dam;
- The FPD had no effect on common carp and crucian carp, perhaps due to the sound waves not strong enough to penetrate their relatively large and elevated bodies;
- Predatory fish, such as perch, pike, pikeperch and snakehead demonstrated passivity in leaving the FPD's coverage area. For these species, the device had an attracting effect.

The most important concomitant result of the study was determining the fish species profile in the area adjacent to the Kokaral Dam. The species diversity with the FPD in the off

mode included 12 species belonging to 4 families: common carp, crucian carp, roach, ide, bream, rudd, sabre carp, asp, snakehead, pikeperch, perch, and pike. By species quantity, the cyprinoids represent the richest family. In terms of abundance and biomass, rudd and perch dominated; the subdominant group included roach and pike. The number of other fish species – except bream and sabre carp – coincides with the data of the earlier studies.

7. Recommendations

A more detailed assessment of the efficiency of the sonar fish protection device installed at the Kokaral Dam in the Small Aral Sea requires further investigation with the account of seasonal weather changes and hydrological instability of the water flow at this specific site. A hydrophone is necessary for executing more thorough research to measure the corresponding sonar sounds generated by underwater speakers (at least 120 phons).

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